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5.13 A STUDY OF THE EFFECTS OF AN ADDITIONAL SOUND SOURCE ON RASS PERFORMANCE

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1. Introduction

The southern great plains (SGP) Cloud and Radiation Testbed (CART) site of the Atmospheric Radiation Measurements (ARM) Program continuously operates a nine panel 915 MHz wind profiler with Radio Acoustic Sounding System (RASS), measuring wind profiles for 50 minutes and virtual temperature profiles for the remaining 10 minutes during each hour. In normal operation four acoustic sources are located at the east, west, north, and south edges of the clutter fence of the profiler (Fig. 1). Each source consists of a commercially available transducer using about 150 W of electric power, pointing downward into an upward-pointing parabolic-dish antenna. Each source produces a relatively broad-angle beam (approximately 12deg). Because the acoustic energy moves with the mean atmospheric wind in addition to the inherent speed of sound (about 340 m/s), four sources (one on each side of the antenna) provide coverage in all wind directions.

It is well recognized that one of the principal limits on RASS performance is high horizontal wind speed (May et al., 1988) that moves the acoustic wave front sufficiently to prevent the microwave energy produced by the radar and scattered from the acousic wave from being reflected back to the radar antenna. With this limitation in mind, the ARM Program purchased an additional, portable acoustic source that could be mounted on a small trailer and placed in strategic locations to enhance the RASS performance (when it was not being used for spare parts). A test of the resulting improvement in RASS performance (or lack thereof) was performed during the period 1995-1997.

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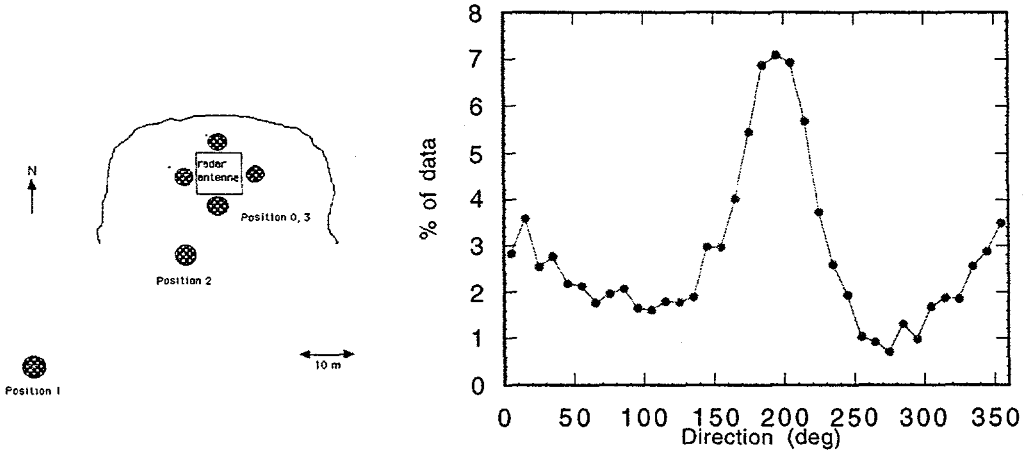

Figure 1. Probability distribution of wind direction averaged over the range of RASS coverage at the CART site's central facility and the selected locations for the portable RASS acoustic source. Positions 1 and 2 indicate alternative locations of the portable source. In positions 0 and 3, the portable source was not used. The jagged line around the radar antenna indicates a natural earthen embankment approximately 4 m high.

2. Description

In 1995-1997 three different configurations (see Table I) of the sources were used. In combination with the default position described in the Introduction, these configurations resulted in four data sets for comparison. Because the prevailing wind at the CART site's central facility is southerly to southwesterly, the two locations

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chosen for the portable source were 35 m southwest of the radar antenna (position 1) and 10 m south-southwest of the antenna (position 2). Only four sources in standard locations were used for position 0 and position 3. Although the locations of the sources for positions 0 and 3 were identical, in the latter case the sources were tilted 3 deg from vertical (away from the radar antenna) to investigate an alternative method of adjusting for the effects of strong horizontal winds without resorting to portable sources.

Table 1. Dates, locations, and number (#) of acoustic sources for each position used in the study.

Position	#	Location	Dates
0	4	Default	7/1/95 - 2/1/96
1	5	35 m sw	2/7/96 - 3/21/96
2	5	11 m ssw	3/21/96 - 7/11/96
3	4	Default (3^o tilt)	7/11/96 - 8/20/97

In retrospect, the length of time (Table I) when position 1 was tested (43 days) might have been too short to obtain representative statistics for all wind speeds, directions, and stability conditions. Position 2 (tested for 112 days) produced better statistics, while position 0 (200 days) and position 3 (405 days) had more than adequate coverage. Stability conditions lend an additional complication to comparisons of this type. RASS coverage often suffers considerably during nighttime compared to daytime coverage (May et al., 1988). This is because atmospheric turbulence during nighttime is often insufficient to "smear" the reflected radar power over relatively large areas; the highly localized spot produced by Bragg scattering of radar energy is unlikely to strike the radar antenna, particularly at large heights.

The data consist of consensus-averaged virtual temperatures, wind speeds, and wind directions produced by the wind-profiling system. From these data, the maximum height above the surface (z_S) of contiguous good data (that is, the maximum height with "good" temperature values obtained before the first "bad" value); the maximum height of good data regardless of values at lower heights (z_m) and the mean virtual temperature (T_{VS}, wind speed (S_S) and wind direction (D_S) through z_S were determined for each hour interval. No additional quality control of the data presented here has been performed to, for example, eliminate bad data points and thus extend the profile. Our experience is that with a conservative set of operating parameters, the contiguous profile is usually quite acceptable.

3. Results

The distributions of S_S and D_S (Fig. 2) are similar for the four periods of interest. The operating period for position 1 had northerly wind conditions more frequently than the other time periods and also experienced strong winds more often. This pattern may have contributed to making the maximum in the probability distribution of z_S for position 1 smaller than that at any other position.

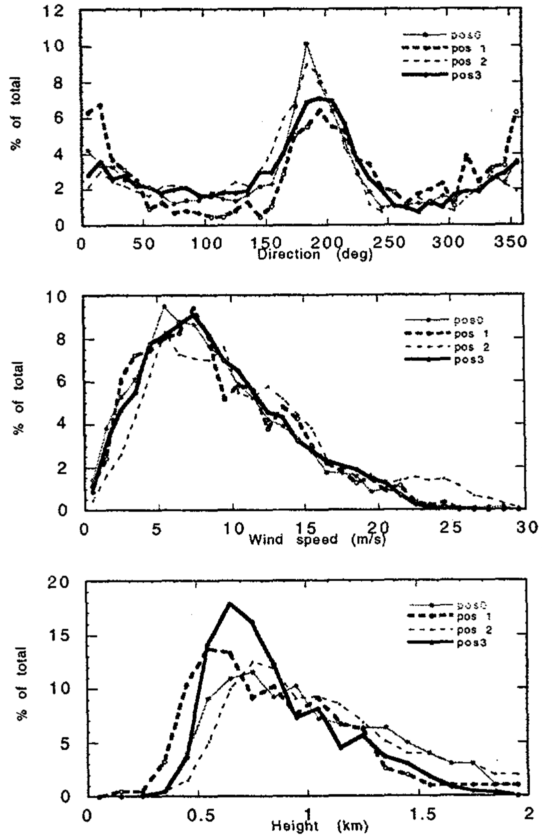

Figure 2. Wind direction, wind speed, and RASS height distributions during the periods defined for each position.

The distributions of z_S as a function of wind direction and position are illustrated in Fig 3. The shift of modal height to larger values when the portable source was used in positions 1 and 2 is immediately apparent when winds were from the southwest (sw) quadrant. The most likely heights are summarized in Table 2. The fact that the shift to larger values occurred only when the winds are

Table 2. Most probable (mp) and mean (mn) maximum RASS height (km) for each position and wind direction quadrant for daytime (06-18 hr) and for nighttime (18-06 hr).

	Direction															
	0-90				90-180				180-270				270-360			
	day		night		day		night		day		night		day		night	
Pos	mp	mn	mp	mn	mp	mn	mp	mn	mp	mn	mp	mn	mp	mn	mp	mn
0	0.95	1.07	0.75	0.96	1.26	1.21	0.65	0.93	0.75	1.05	0.65	0.78	0.95	1.01	0.75	0.89
1	0.64	0.87	0.55	0.83	1.04	0.92	0.64	0.73	1.14	0.99	1.04	0.80	0.65	0.76	0.55	0.77
2	1.05	1.19	0.66	0.93	1.25	1.21	0.75	0.68	1.15	1.11	0.75	0.88	1.04	1.02	0.85	0.87
3	1.15	1.05	0.76	0.83	1.27	1.10	0.65	0.83	0.75	0.93	0.54	0.70	0.85	0.96	0.65	0.81

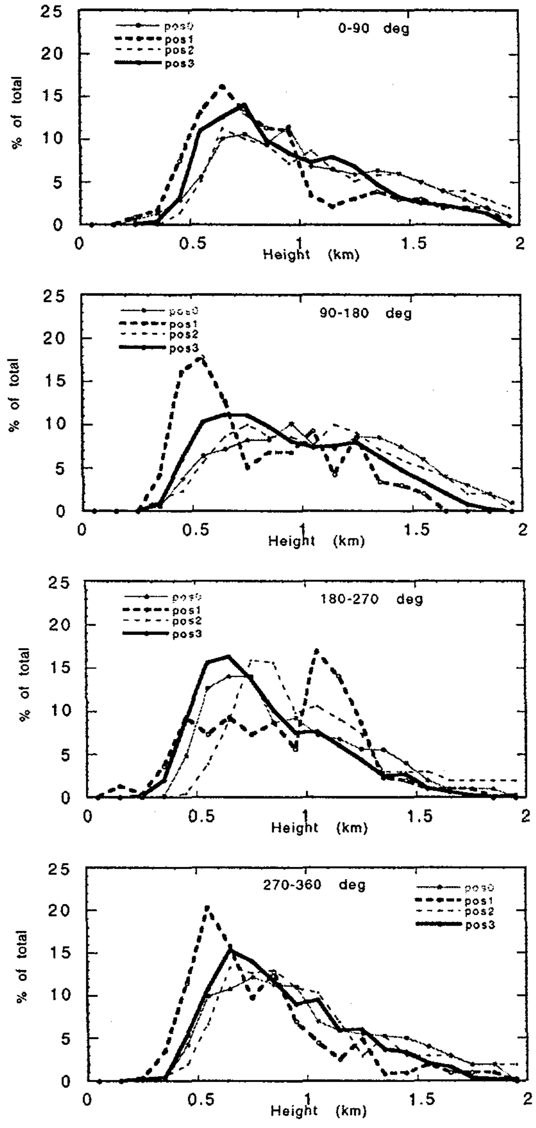

Figure 3. Distribution of maximum RASS height (with continuous data from the initial range gate) for each wind direction quadrant (averaged through RASS height) at each position.

from the quadrant containing the portable source indicates that the increase in z_S is not due solely to an overall increase in acoustic energy in the sample volume because of the additional sound source. The marked difference in most likely height between position 1 and position 2 for southwest winds (1.05 km versus 0.75 km) should be viewed with caution becuse, although the two positions have similar values of most likely wind speed, position 1 has significantly more cases of weak winds (less than 10 m/s), and position 2 has significantly more cases of strong winds (greater than 20 m/s).

A better measure of the effectiveness might be the distribution of the "displacement distance" which we define as

$$z_d = z_s S_s / c$$

where c is the speed of sound. This quantity is the horizontal distance the acoustic wave front will move during the time it takes the wave front to travel vertically to the maximum RASS height. Figure 4 shows that both positions 1 and 2 effectively increased this value over position 0 or 3. This is the horizontal distance an air parcel would travel in the time it took the acoustic energy to reach the maximum contiguous RASS height. Position 1 produced a bimodal distribution that probably resulted from its relatively small sample size. It is not possible to determine at this time whether position 1 or position 2 is "better" because

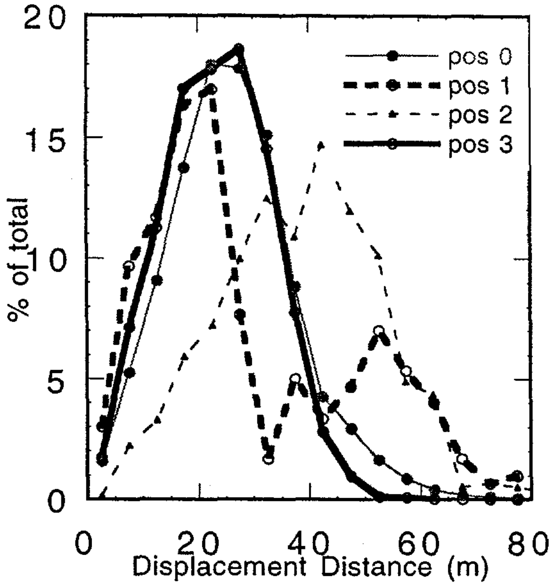

Figure 4. Distribution of so-called displacement height, defined in the text for wind directions between 180 and 270 deg.

of the inadequate amount of data obtained from position 1. This problem can be seen again in the rate of decrease of z_S with S_S (Figure 5). Here the mean value for z_S has been calculated for different ranges of S_S for each position and quadrant of wind direction (although only the sw quadrant is shown). In the default configuration and for position 3, the rate of decrease is well defined at -30 $m(m/s)^{-1}$. A similar rate is determined for position 2, but with a higher intercept and thus larger overall values. Position 1, however has a much slower decrease (-7 $m(m/s)^{-1}$), but a significantly lower intercept. This result was heavily influenced by the small amount of data. For example, there are only two values in the 0-1 m/s range for sw winds. We would expect the intercepts for positions 1 and 2 to be similar with adequate data. It is interesting to note that as wind speeds continue to increase, z_S approaches a constant value near 0.5 km.

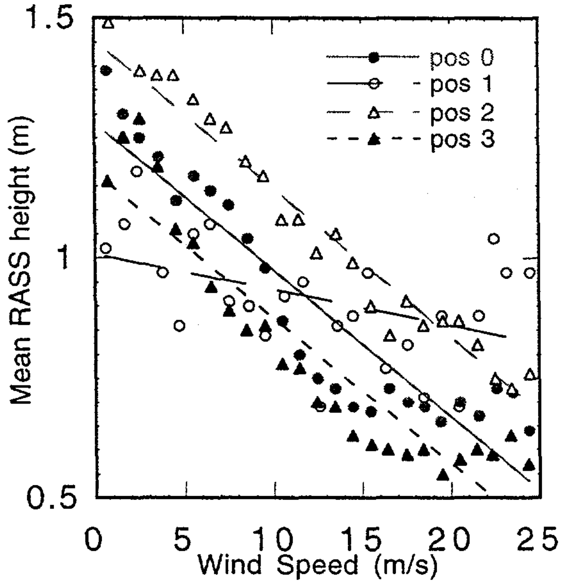

Figure 5. Values of mean RASS height calculated for 1-m/s wind speed increments for each position when winds were from the sw quadrant. Lines are the best fit to the data in each case. Large scatter in data for position 1 is due to the relatively small number of data points at that location.

The probability distribution for data in position 3 is difficult to explain. Tilting the RASS sources slightly away from the antenna was expected to provide acoustic energy in the upwind direction, regardless of wind direction. Tilting the sources only 3 deg from vertical, should decrease the acoustic energy directly above the radar antenna only slightly in calm conditions (because the beam width of the acoustic sources is larger than 3 deg); on the other hand, more energy upwind should aid in obtaining data to larger heights in stronger winds. For winds near 15 m/s, tilting the sourcest might be expected to be ideal. However, this was apparently not the case. The peak in the distribution of heights was shifted to lower heights for position 3 relative even to position 0, and the mean height was about 10% lower in position 3 than position 0 (Table 2). Apparently, the decrease in energy density directly above the radar antenna that resulted from tilting the acoustic sources was more significant than the increase in acoustic energy upwind. Some degradation of performance of the system with time is also possible. This will be determined from data presently being taken with the system returned to position 0.

The effect of stability on the maximum height is clearly evident in Fig. 6. An obvious shift toward lower heights during nighttime is evident. The distribution during daytime is more even up to more than 1 km, while nighttime stable conditions contributed strongly to limiting the overall most probable height to less than 1 km. Thus, the peaks in the overall distributions between 0.5 and 0.8 km are due mostly to nighttime stability.

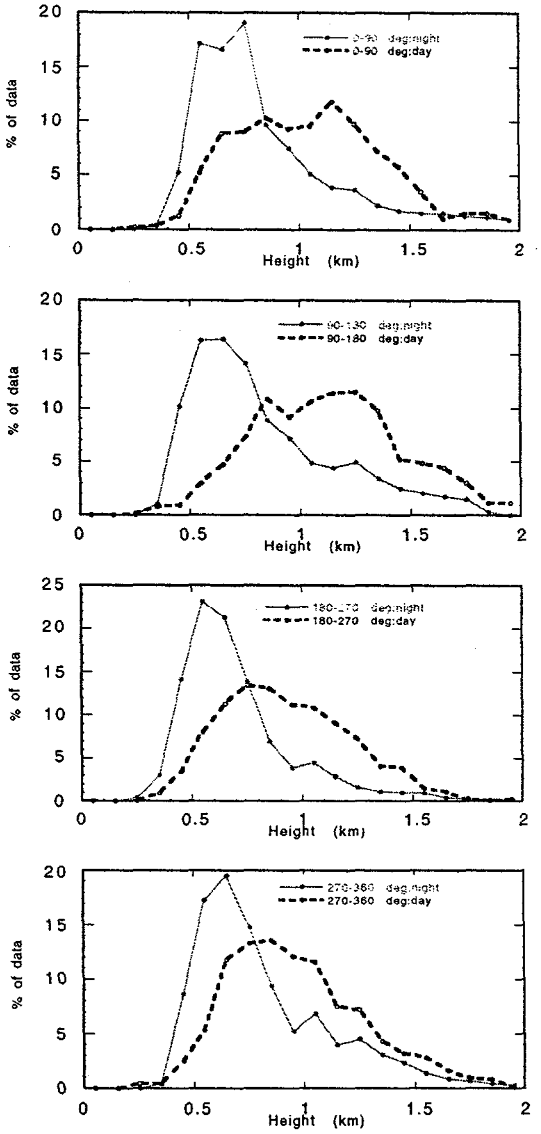

Figure 6. Distribution of RASS maximum height during daytime and nighttime in position 3.

4. Conclusion

The use of a portable, additional sound source to augment RASS operation was successful. An increase of 300 m in the most probable maximum height was observed for winds aligned with the portable source, while the mean height increased by approximately 80 m. Attempts to improve performance by tilting the four stationary sources away from the radar antenna by 3 deg were not successful. Studies are continuing to determine whether this resykt was due to system degradation with time.

Acknowledgment

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